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C TITLE OF THE INVENTION

Arrangement of a Heating Layer for a High-Temperature Gas Sensor

C FIELD OF THE INVENTION

Sub 47 The invention relates to an arrangement of a heating layer for a high-temperature gas sensor according to the preamble of the claim 1.

C BACKGROUND INFORMATION

Sub 67 Sensors that are used in the exhaust gas of a combustion engine must not only be high-temperature stable, but rather they must typically also be regulated to a determined operating temperature, because both the temperature of the exhaust gas as well as the exhaust gas throughput are dependent on the operating state of the engine and vary strongly. Typically such sensors are operated at several hundred degrees Celsius. A typical example therefor is the λ -sonde which can be operated at temperatures up to 1000°C.

Sub 63 15 New types of planar exhaust gas sensors, which are presently being produced by various manufacturers, consist of a structure as is shown in Fig. 1a, 1b and 1c in various perspectives. In this context, Fig. 1a shows the top side of the sensor as a plan view, Fig. 1b shows the sensor in a side view on the section location marked with a dashed line, and Fig. 1c shows the bottom
20 side of the sensor in a plan view. For orientation, a coordinate

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system with an x-, y- and z-axis is drawn in. The Figures show an elongated rectangular carrier 1, also called a transducer, which generally consists of an electrically insulating substrate, and on the underside 5 of which, a heating layer 8 is applied as shown in Fig. 1b and 1c. This heating layer 8 comprises a heating conductor path 6 and a supply line part 2. The heating conductor path 6 is located on the sensor bottom side under the functional layer 4, which is arranged on the sensor top side 7. The functional layer 4 determines the special characteristics of the sensor, such as, for example, the selectivity for a certain gas or the like. Then, an electrode structure 3 adapted to the special requirements is applied on the sensor top side 7 under the functional layer 4. A temperature that is constant over the location must prevail on the sensor tip 10 on the sensor top side 7, in the area in which the functional layer 4 is applied. This constant temperature is achieved with the aid of the heating layer 8 and a temperature sensor or feeler, which is not shown in this illustration and is located on the sensor bottom side. Thereby the functional layer 4 is regulated to a determined temperature, the so-called operating temperature.

A further function of the elongated appearing carrier is to ensure that the temperature on the side facing away from the sensor tip 10, the so-called sensor connection side 9, is so low that synthetic plastic insulated cables can be applied as measuring lines or as power supply lines on the end of the supply line part 2 of the heating layer 8.

For the functioning of the sensor, it is of decisive significance, how constant the temperature profile is on and over the functional layer 4, and how exactly the operating temperature can be regulated.

5 In the application example, the heating conductor path 6 is arranged as a heating meander. The uniform zig-zag shaped meander band runs parallel to the y-axis. The constant height A of the meander here corresponds to the length L of the functional layer 4 lying thereover. The width b of the heating conductor path 6 is constant. The two ends of the heating conductor path 6 are connected with the supply line part 2 of the heating layer 8. The supply line part 2 of the heating layer 8 is guided to the sensor connection side 9.

In the EP 0,720,018 A1, a heating layer for an exhaust gas sensor is disclosed, in which the heating conductor path 6 is arranged in a serpentine shaped manner. The spacing distance of the serpentines among each other is always the same. This form similarly corresponds to a uniformly modulating meander band that runs parallel to the y-axis of the sensor.

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In the U. S. 5,430,428, DE 43 24 659 C1 and DE 198 30 709, similarly, forms for the extending path or progression of the heating conductor path in an exhaust gas sensor are disclosed. In this context, the heating conductor path is arranged in a meandering shape. In this context, however, the uniformly modulating mean-

der band is arranged rectangularly and also runs parallel to the y-axis of the sensor.

In all of these publications, the heating conductor path has the form of a uniformly modulating meander band. The height A of the meander band is constant during the entire extension or path progression.

A similar construction of various gas sensors is also described in the script "Industrial Gas Sensor Arrangements", especially in part 4 by K. Ingrisch: "Semiconductor Gas Sensors" of the Instruction Course 22904/41.551 at the TAE Esslingen; G. Wiegler (production); Esslingen 1997 and in the SAE-Paper 960692 by K. Ingrisch et al.: "Chemical Sensors for CO/NO_x-Detection in Automotive Climate Control Systems".

Arrangements of the heating layer 8 in high-temperature gas sensors are also known in which the heating conductor path 6 forms a meander band, which, beginning at the supply line part 2, first extends uniformly modulating on the one side parallel to the x-axis, and then extends in a straight line along the sensor tip parallel to the y-axis, and then again extends on the other side uniformly modulating parallel to the x-axis back to the supply line part 2. The width b of the heating conductor path 6 is not varied. The length L of the region in which the heating conductor path 6 is arranged, corresponds to the length L of the functional layer 4 lying thereover. Such a construction is disclosed, for example, in the DE 198 48 578 A1.

It is disadvantageous in all of the previously described arrangements, that a temperature gradient arises along the lengthwise axis x of the sensor, necessitated by the good thermal conductivity of the typically utilized Al_2O_3 substrate. This temperature gradient is subject to very large fluctuations. Thus, for a rated temperature of, for example, 600°C , this temperature gradient typically amounts to approximately 80°C over the length L of the functional layer 4, as it is shown in Fig. 2b. In Fig. 2b, the temperature at various points on the sensor top side is illustrated.

In order to make the temperature distribution on the sensor top side more homogeneous, it is suggested in the EP 0,477,394 to build up or construct the heating conductor paths on the sensor tip in the form of a ladder, whereby the ladder pattern contains a plurality of parallel circuit-connected individual conductors, which can be arranged in such a manner so that a homogeneous temperature distribution can be adjustably set over the length. In this context, both the width or the cross-section of the various heating conductor paths as well as the spacing between two heating conductor paths, which represent the spokes of the ladder formation, can vary.

It is disadvantageous in this publication, however, that due to the parallel circuit connection, the resistance of the heating conductor paths is reduced so far or so low that it is no longer possible to establish a resistance in the range of several ohms for the same specific resistance of the heating conductor path

resistance (generally platinum), because otherwise the layer thickness of the structure would have to become so thin that it could no longer be produced by thick layer or thick film technology.

5 In the DE 195 23 301, a heating arrangement for a high-temperature metal oxide sensor is disclosed, in which a substrate is provided, on which, in addition to the two supply line parts of the heating layer, two measuring conductor paths are arranged, which are connected to the heating conductor path, and wherein one or more connection lines are secured to a location on the supply line part of the heating layer that is as far away as possible from the heating conductor path. This arrangement in four wire technology is illustrated as a substitute circuit diagram in Fig. 3. That means, that in addition to the wide supply line parts of the heating layer, two additional measuring lines are introduced, on which the voltage drop over the heating resistance of the heating conductor path is tapped or taken-off. In this arrangement, it is irrelevant how large the resistances R_{Z1} and R_{Z2} of the supply line parts of the heating layer are, because the voltage U_M is directly taken-off or tapped on the heating resistance R_H of the heating conductor path. Since the voltage U_M is measured in a zero-current condition, no voltage will drop across the two tapping resistors R_{A1} and R_{A2} . The resistance can be determined as $R_H = U_M/I_0$ from the measured current I_0 and the voltage U_M . A simplified embodiment thereof is also known as state of the art, namely the so-called three-wire technology. If one assumes the two resistances of the

supply line parts of the heating layer to be equal, then one can omit one of the two voltage taps. Then, one must only still measure the total voltage U_0 and then obtains: $R_H = (2xU'_M - U_0)/I_0$. One measuring conductor and one connection contact are saved through this three-wire technology.

It is disadvantageous in this publication, however, that the temperature profile of the sensor is not constant over the length L in the x -direction, and thus the heating resistance of the heating conductor path is only to be regarded as an average value over the entire range L . Therefore, a regulation can similarly only be achieved very inexactly therewith. This is especially of disadvantage, if the temperature of the sensor housing changes strongly, as is the case, for example, in the exhaust gas of an automobile, because then the temperature gradient similarly strongly varies over the sensor chip, and thus R_H can be allocated to no temperature of the functional layer.

SUMMARY OF THE INVENTION

It is the object of the invention to arrange the heating conductor path(s) in such a manner so that the same temperature prevails at each location of the functional surface of the sensor.

It is a further object of the invention to provide a fundamental basis with which an exact temperature determination, and connected therewith, an exact temperature regulation on the functional surface, is made possible.

This object is achieved according to the invention by the features in the patent claim 1. In this context, the meander-shaped

heating conductor path comprises different partial heating resistances in different partial sections with reference to the x-axis. The height or magnitude of the partial heating resistance is dependent on the spacing distance relative to the sensor tip.

Advantageous further embodiments are defined by the dependent claims. Hereby, the partial heating resistance decreases or diminishes in a direction toward the sensor tip. This is achieved in that the path length of the heating conductor path and therewith of the meander band varies from partial section to partial section. In this context, the path length of the heating conductor band is given if one would pull apart the meander band like a thread that is looped or tangled in itself. The width of the heating conductor path can also vary in various partial sections, alone or together with the path length. Moreover, in addition to the supply lines of the heating layer, measuring supply lines are also applied, with which the exact temperature can be obtained, so that an exact temperature regulation is made possible. In a further advantageous embodiment, the heating resistance to be measured can be adjustingly set, so that plural sensors comprise an identical resistance/temperature characteristic curve.

The advantages achieved with the invention consist in that the sensor, and especially the functional surface of a high-temperature gas sensor, can be adjustingly set to an exact temperature, which then prevails at each location on the functional surface.

The heated surface then comprises a minimal temperature gradient. The temperature measurement provides more exact results and the entire high-temperature gas sensor works with a higher accuracy. Also, thereby the sensors may be normed or normalized among one another, so that the same temperature can be allocated for the same measured heating resistance of various sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention shall be described in the following in greater detail in connection with example embodiments and the Figures.

Fig. 1a shows the top side of a high-temperature gas sensor according to the prior art.

Fig. 1b shows the side view of a high-temperature gas sensor according to the prior art.

Fig. 1c shows the bottom side of a high-temperature gas sensor with a first heating layer according to the prior art.

Fig. 2a shows the bottom side of a high-temperature gas sensor with a second heating layer according to the prior art.

Fig. 2b shows the temperature distribution for a high-temperature gas sensor with the heating layer shown in Fig. 2b.

Fig. 3 shows the circuit for the temperature measurement on a high-temperature gas sensor according to the prior art.

Fig. 4a shows the first heating layer with a meander-shaped heating conductor path and different partial resistances.

Fig. 4b shows the diagram of the temperature distribution for a high-temperature gas sensor with a heating conductor path shown in Fig. 4a.

Fig. 5a shows the second heating layer with a meander-shaped heating conductor path and different partial resistances.

Fig. 5b shows the diagram of the temperature distribution for a high-temperature gas sensor with a heating conductor path shown in Fig. 5a.

Fig. 6 shows the heating layer with a first additional arrangement for measuring lines for the temperature determination.

Fig. 7 shows the heating layer with a second additional arrangement for measuring lines for the temperature determination.

Fig. 8 shows the heating layer with a third additional arrangement for measuring lines for the temperature determination.

Fig. 9 shows the heating layer with a fourth additional arrangement for measuring lines for the temperature determination.

Fig. 10 shows the heating layer with a fifth additional arrangement for measuring lines for the temperature determination.

Fig. 4a shows a heating layer arrangement with a heating conductor path 6, of which the extending path or progression forms a meander-band, which, beginning on the supply line part 2, first extends modulatingly on the one side parallel to the x-axis, and then extends in a straight line along the sensor tip parallel to the y-axis, and then again extends on the other side modulatingly parallel to the x-axis back to the supply line part 2. In this context, the heating layer 8 was produced with a platinum thick film paste, which was applied by a screen printing technique onto an aluminum oxide substrate and thereafter was fired. For achieving a homogeneous temperature profile, the partial heating resistance in the x-direction was varied. The partial heating resistance is proportional to the quotient of the path length l and the width of the heating conductor path b relative to a path distance in the x-direction. In order to adapt the heating resistance to the desired temperature profile, that is to say the

same temperatures over the entire functional layer, in the example embodiment, the path length 1 of the heating conductor path 6 is shortened from partial section to partial section, in that the height of the meander-band 11 is constantly reduced. It would also be exactly as effective to reduce the modulation rate, namely the frequency of the direction change of the meander-band 11, with reference to a path distance in the x-direction.

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The relationship between the path length of the heating conductor path 6 and the proportion of the path distance covered or traversed in the x-direction is important. Thereby, the partial heating resistance per unit length in the x-direction can be varied. Thus, different energy quantities can be supplied to the functional layer at different locations.

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In this application example, a constant heating conductor path width b of $b \approx 300 \mu\text{m}$ was selected. It is also evident in this illustration, that the area or region in which the heating conductor path 6 is applied, is substantially longer than the length L of the functional layer lying thereover. The heating conductor path 6 arranged in a meander-shape, which is arranged between the end of the functional layer 4 lying thereover and the supply line part 2, serves to compensate and to provide counter heating for the heat flow to the sensor connection side 9. In order to achieve this, most of the heating power, that is to say the greatest proportion on the entire length of the heating conductor path is required. The high resistance value per unit length in the x-direction is achieved by the long winding path of the

heating conductor path. Which resistance value is required at which location can either be calculated or determined by experiments.

Fig. 4b shows the temperature distribution curve along the x-axis for a high-temperature gas sensor with a heating conductor path shown in Fig. 4a. In this context, the temperature along the x-axis over the entire sensor is detected or obtained dependent on the spacing distance relative to the sensor tip. It can be seen that the temperature in the region of the length L of the functional layer comprises only a very small temperature fluctuation ΔT in the x-direction. Compared to the temperature distribution shown in Fig. 2b, there is achieved a temperature fluctuation ΔT that is smaller by 60°C.

Fig. 5a shows a heating layer arrangement with a heating conductor path 6, of which the extending path or progression forms a meander-band, which, beginning on the supply line part 2, first extends modulatingly on the one side parallel to the x-axis, and then extends in a straight line along the sensor tip parallel to the y-axis, and then again extends on the other side modulatingly parallel to the x-axis back to the supply line part 2. In this context, the heating layer 8 was produced with a platinum thick film paste, which was applied by a screen printing technique onto an aluminum oxide substrate and thereafter was fired. For achieving a homogeneous temperature profile, the partial heating resistance in the x-direction was varied. The partial heating resistance is proportional to the quotient of the path length l

and the width of the heating conductor path b relative to a path distance in the x -direction. In order to adapt the heating resistance to the desired temperature profile, that is to say the same temperatures over the entire functional layer, in the example embodiment, the path length l of the heating conductor path 6 is shortened from partial section to partial section, in that both the height A of the meander-band 11 as well as the modulation rate, i.e. the frequency of the direction change of the meander-band 11 in the x -direction, and the width b of the heating conductor path are varied, so that the partial heating resistance decreases or diminishes toward the sensor tip.

The relationship between the path length of the heating conductor path 6 and the proportion of the path distance covered or traversed in the x -direction is important. Thereby, the partial heating resistance per unit length in the x -direction can be varied. Thus, different energy quantities can be supplied to the functional layer at different locations. Also the width b of the heating conductor path is of significance. The shorter the path length of the heating conductor path and the larger its width in a partial section, the smaller is the partial heating resistance of the heating conductor path region, and thus, the smaller is the heating in this region.

In this application example, the heating conductor path comprises varying widths b . In the two sections that extend along to the x -axis, the heating conductor path width amounts to $b \approx 300 \mu\text{m}$. On the straight section, which extends parallel to the y -axis on

the sensor tip, the value increases to $b \approx 600 \mu\text{m}$. Also here, the heating conductor path arranged in a meander-shape, which is arranged between the end of the functional layer 4 lying there-
over and the supply line part 2, again serves to compensate and
to provide counter-heating for the heat flow to the sensor con-
nection side 9. In order to achieve this, the most heating
power, that is to say the greatest proportion on the path length
of the heating conductor path is needed. In this application
example, it is not absolutely necessary, that the two meander-
shaped partial parts are axially symmetrical. The required
resistance values may also be achieved by a variation of other
parameters. They also need not extend exactly parallel. This
is, however, especially advantageous, if the temperature gradient
in the y-direction shall be very small, because then the curve
progression does not need to be separately determined once again.

Fig. 5b shows a diagram of the temperature distribution for a
high-temperature gas sensor with a heating conductor path shown
in Fig. 5a. In this context, the temperature along the x-axis
over the entire sensor is determined or obtained dependent on the
spacing distance relative to the sensor tip. It can be seen that
the temperature fluctuation ΔT in the region length L of the
functional layer has been further reduced in comparison to
Fig. 4b.

From the previously described example embodiments it becomes
clear, that the characteristic values, the width b of the heating
conductor path and the path length l of the heating conductor

path, are varied in order to obtain a homogeneous temperature distribution. These characteristic values can be varied both individually as well as in all possible combinations, during the heating conductor path progression. Thereby, the path length can be varied both by the height A of the meander-band 11 as well as by the modulation rate, i.e. the frequency of the direction change in the x-direction of the meander-band 11.

In the further Figures, embodiments are presented, which make it possible, due to the homogeneous temperature distribution, to determine the temperature on the sensor surface exactly in the region in which the functional layer is located.

Fig. 6 shows a heating layer with a first additional arrangement for measuring lines for the temperature determination. Here, two further paths 12 which serve as voltage taps, are applied parallel to the broad supply line parts 2 of the heating layer. They are guided from the two ends of the heating conductor path 6 to the sensor connection side 9. By this arrangement, the supply line resistance, that is to say the voltage drop over the supply line parts 2, is compensated over the path distance Z, but the portion of the resistance in the region G, which serves for the counter-heating, is also measured together. Since, however, the largest temperature gradient lies in the region G, as described in the preceding example embodiments, and because the greatest portion of the total path length of the heating conductor path 6 is provided at G, the resistance arises as a combination of the resistance portions of the heating conductor path of the partial

path distances G and L. Only the resistance portion at L is measured at a temperature that is constant in the region of L. If the temperature gradient at G is the same for all conditions, then the measuring result can be exactly evaluated.

5 With strongly fluctuating surrounding environmental temperatures, which is the case, for example, in an application in the exhaust gas of an automobile, the temperature gradient in the region of G will vary. Then it makes sense to arrange the measuring lines as it is described in Fig. 7.

In Fig. 7 and 8, two measuring conductor paths 12 for temperature determination are similarly applied. Here, however, the voltage is tapped in a region at which a constant temperature prevails. That is to say, the measuring conductor paths 12 can be applied everywhere on the heating conductor path 6, somewhere in the region of L at a desired location, in a symmetrical manner. Here it is similarly possible, through the measurement of the resistance, to measure and therewith also regulate the temperature.

In Fig. 9, two asymmetrical measuring conductor paths 12 for the temperature determination are applied. Here the voltage is also
20 tapped in a region at which a constant temperature prevails. That is to say, they can be applied everywhere on the heating conductor path 6, somewhere in the region of L, at a desired location, in an asymmetrical manner. Here it is similarly possible, through the measurement of the resistance, to measure and
25 therewith also regulate the temperature.

Fig. 10 shows a heating layer with a variable arrangement for measuring conductor paths 12 for the temperature determination. In this context, the voltage taps are applied at various different locations 13 within the path distance L. In the further production process, the individual voltage taps can be severed or trimmed in such a manner by means of a laser method so that only one connection remains, which offers exactly the desired resistance value. In this manner, fluctuations during the production, for example of the layer thickness or of the specific resistance of the heating conductor path material, can be compensated, in order to obtain thereby a constant relationship between measured resistance value and temperature for all sensors. In this context, also the total resistance of the heating conductor path 6 remains unchanged. Sensors fabricated in this manner will then all comprise a common resistance-temperature characteristic curve. Contrary to conventional structures, for which complicated trimming must be carried out on the sensor connection side through variation of the total resistance, here the trimming takes place by variation of the voltage tap on the high-temperature side.

It is evident for all applications, that the measuring conductor paths cannot only be fabricated as shown in the four-wire technique, but also analogously may be fabricated in the three-wire technique, as already described in Fig. 3.

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